Free Flight Program

Performance Metrics Results to Date

December 2003 Report

INTRODUCTION

This is the eighth semi-annual report on Free Flight Program (FFP) performance metrics. This report focuses on changes in the efficiency and capacity at specific locations in the National Airspace System associated with the implementation of Free Flight capabilities. The primary capabilities studied are the Traffic Management Advisor (TMA), User Request Evaluation Tool (URET), and Collaborative Decision Making (CDM). Performance metrics analyses in this report address both implementations at new sites as well as functionality enhancements at existing sites.

The primary performance goals of the Free Flight Program are to increase capacity of airports and airspace, and to improve efficiency (reduced flight time and fuel usage) while maintaining the current high level of safety. The purpose of continuing measurement is to determine whether tools are being used as expected and whether anticipated benefits to users are being realized. Many of the metrics used in this report can be converted into delay savings, which is a common measure of user value. Findings from metric analyses are also used in developing business cases for continuing deployment to new sites and implementing capability enhancements at existing sites. Analysis included in this report, for example, shows a reduction in gate delay and flight times that can be associated with an enhancement to TMA that allows adjacent Centers to efficiently schedule departure aircraft into the metered flow.

In-depth discussions with air traffic controllers who use the Free Flight tools are an integral part of metrics analysis. These discussions often focus the analyses on specific conditions where the tools are providing benefit. After initial implementation, facilities may only use tools at certain times of the day or under specific conditions. TMA usage under visual and instrument meteorological conditions for specific runway configurations are examples of a focused analysis. The Free Flight metrics team has developed detailed databases that allow analyses to be focused on specific conditions or airport configurations.

The FFP metrics team was established at the beginning of Free Flight Phase 1 with the goal of evaluating the user benefits of Free Flight deployments. The approach used to measure operational impact was developed in collaboration with the RTCA Free Flight Steering Committee. The metrics team now includes research analysts, database specialists, and air traffic controllers from the following organizations: the Federal Aviation Administration (FAA), CNA Corporation (CNAC), MITRE Center for Advanced Aviation System Development (CAASD), Jerry Thompson and Associates (JTA), the National Center of Excellence for Aviation Operations Research (NEXTOR), and Crown Consulting.

If you have questions or comments on this document or the FFP metrics program please contact Dave Knorr at 202-220-3357 or Ed Meyer at 202-220-3407.

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1.0 SAFETY

As the Free Flight Program develops and deploys tools throughout the National Airspace System (NAS), the effects of these tools are continuously monitored to ensure that the highest standards of safety are maintained. There is an increasing belief that these tools enhance the safety of the system. For example, Controller Pilot Data Link Communications (CPDLC) may reduce communication errors, and User Request Evaluation Tool (URET) and Traffic Management Advisor (TMA) increase situational awareness and alert controllers to potential conflicts. Increased situational awareness should reduce operational errors.

1.1 System Safety Assessment

The Free Flight System Safety Workgroup continues to participate with the FAA System Safety Work Group (FAA SSWG) to assess what impact URET, TMA, and CPDLC have on the NAS and the controller workforce, and whether these tools have a relationship to operational errors. The System Safety Assessment requires the following actions:

1. Review Program Trouble Reports (PTRs), identifying those with safety implications. Track these PTRs to closure while ensuring this is accomplished in a timely manner.
2. During Free Flight tool implementation, identify any safety related issues and validate them. Elevate validated issues to the appropriate Program Manager.
3. Review any operational error, operational deviation, accident, or incident where URET, TMA or CPDLC was indicated to be a contributing factor.
4. Submit Special Emphasis items, which contain information on Free Flight tools and safety, to Air Traffic and Airways Facilities.
5. Conduct site visits to evaluate identified severe safety risks and make recommendations for resolution.
6. Brief the Free Flight System Safety Workgroup at each meeting on safety related issues identified during the assessment period.
7. The Independent System Safety Assessment is an ongoing process and will continue throughout the life of the Free Flight Program.

1.2 Free Flight System Safety Workgroup Activities

The Free Flight SSWG is tasked with monitoring Free Flight tools during and after installation to ensure all safety concerns are known and addressed promptly. The workgroup has been meeting on a quarterly basis to discuss all safety aspects of URET, TMA, and CPDLC. The workgroup consists of a chairperson from the Free Flight Integration Team and members from the URET, TMA, and CPDLC program offices. In addition, there are representatives from the Office of System Safety (ASY), Office of System Architecture and Investment Analysis (ASD), and the Operational Support Office (AOS).

The Free Flight Program Office (AOZ), in conjunction with Air Traffic Investigations and Evaluations Staff, reviews all operational errors and deviations occurring in the en route environment to ensure that Free Flight tools were not contributing factors to the events, even though during granted periods of immunity the tools were claimed to be. To date, none of the Free Flight tools have been identified as the main causative factor for any operational error or deviation.

2.0 USER REQUEST EVALUATION TOOL (URET)

URET is a decision support tool designed to aid Air Route Traffic Control Center (ARTCC, or more commonly, Center) controllers in the en route environment. The primary function of URET is to alert controllers to potential conflicts between aircraft (up to 20 minutes in advance of the conflict) and to potential conflicts between aircraft and airspace (up to 40 minutes in advance). URET provides controllers with a trial planning capability to create a conflict-free flight plan amendment that can be sent directly to the Host Computer. URET also manages flight data electronically, reducing the need for paper strips. URET has been shown to increase the number of direct routings given to aircraft, and to reduce the number of static altitude restrictions in place at the Centers [1-9].

Prototype URET systems developed by MITRE were in use at two ARTCCs, Indianapolis Center (ZID) and Memphis Center (ZME), for several years before Lockheed-Martin-built production versions were deployed. The prototype variants with two-way Host communication provided capabilities comparable to those of the production systems. The first production version of URET, known as the Core Capability Limited Deployment (CCLD), was installed at six ARTCCs between December 2001 and April 2002; included in the CCLD deployment were replacements for the prototype sites. Beginning in August 2003 at Jacksonville Center (ZJX), the Phase 2 version of URET began to be deployed, and will be rolled out to all twenty ARTCCs in the continental U.S. over the next two years. In addition to ZID, ZME, and ZJX, URET is currently deployed at Kansas City, Cleveland, Chicago, Washington, Fort Worth, and Minneapolis Centers (ZKC, ZOB, ZAU, ZDC, ZFW, and ZMP respectively). The Initial Daily Use (IDU) dates (when controllers began routinely using URET) for the prototypes, CCLD, and URET Phase 2 are shown in Table 1.

Table 1. URET Initial Daily Use (IDU) Dates

ARTCC	Two-Way Prototype	CCLD	Phase 2
ZID	June 29, 1999	January 26, 2002	
ZME	June 29, 1999	January 27, 2002	
ZKC		December 3, 2001	September 14, 2003
ZOB		January 28, 2002	
ZAU		February 25, 2002	
ZDC		April 12, 2002	
ZJX			August 26, 2003
ZFW			November 14, 2003
ZMP			December 5, 2003

2.1 Description

The key URET capabilities include:

- Trajectory modeling
- Aircraft and airspace conflict detection
- Trial Planning to support conflict resolution of user or controller requests
- Electronic flight data management.

URET processes real-time flight plan and track data from the Host computer system. These data are combined with local airspace definitions, aircraft performance characteristics, and winds and temperatures from the National Weather Service to build four-dimensional flight trajectories for all flights within or inbound to the airspace controlled by the ARTCC. URET also provides a “reconformance” function that continuously adapts each trajectory to the observed position, speed, climb rate, and descent rate of the modeled flight. Neighboring URET systems can exchange flight data, position, reconformance data, and status information in order to model accurate trajectories for all flights up to 20 minutes into the future.

URET maintains “current plan” trajectories (i.e., those that represent the current set of flight plans in the system) and uses them to continuously check for aircraft and airspace conflicts. When a potential conflict is detected, URET determines which sector to notify and displays an alert to that sector up to 20 minutes in advance for aircraft-to-aircraft conflicts and up to 40 minutes in advance for aircraft-to-airspace conflicts. Trial planning allows a controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. The controller can then send the trial plan to the Host as a flight plan amendment.

These capabilities are packaged behind a Computer Human Interface (CHI) that includes both textual and graphical information. The text-based Aircraft List helps the controller manage flight data electronically, reducing the dependence on paper flight strips. The Plans Display manages the presentation of current plans, trial plans, and conflict probe results for each sector. The Graphic Plan Display (GPD) provides a graphical capability to view aircraft routes and altitudes, predicted conflicts, and trial plan results. In addition, the point-and-click interface enables quick entry and evaluation of trial plan routes, altitudes, or speed changes, and enables the controller to send flight plan amendments to the Host. For more details about URET capabilities, benefits, and the operational concept, please see [1].

2.2 Operational Use

The operational use of URET is gauged by measuring the number of trial plans created and the number of amendments sent to the Host through URET. Data obtained directly from the Host and URET allowed measurement of the number of direct amendments, which are those that decrease distance flown, measured from the point of the amendment to the destination airport.

Table 2 shows the yearly average number of direct amendments per day initiated by HOST and URET, the yearly average number of URET-initiated direct amendments per day, and the percentage of directs initiated by URET for December 2002 through November 2003 at sites which have been operating for at least a year (ZID, ZME, ZKC, ZOB, ZAU, and ZDC). Between 15 and 30 percent of the amendments at ZID, ZME, ZKC, and ZOB were entered using URET, and over half were generated by URET at ZDC.

Table 2. Yearly Average Directs per Day for Phase 1 Sites

ARTCC	Host and URET	URET Only	Percent from URET
ZID	3430	712	21
ZME	1697	531	31
ZKC	1528	253	17
ZOB	2298	406	18
ZAU	2176	315	14
ZDC	1964	1167	59

URET was deployed to three new centers since the last Free Flight Metrics Report. Figures 1 and 2 show the monthly average number of direct amendments per day initiated by HOST and URET and the monthly average number of URET-initiated direct amendments from IDU through November 2003 for ZJX and ZFW, respectively. (ZMP, the newest URET site, has not reported metrics data at the time of this report.) Both sites show a rapid increase in the number of URET-initiated directs.

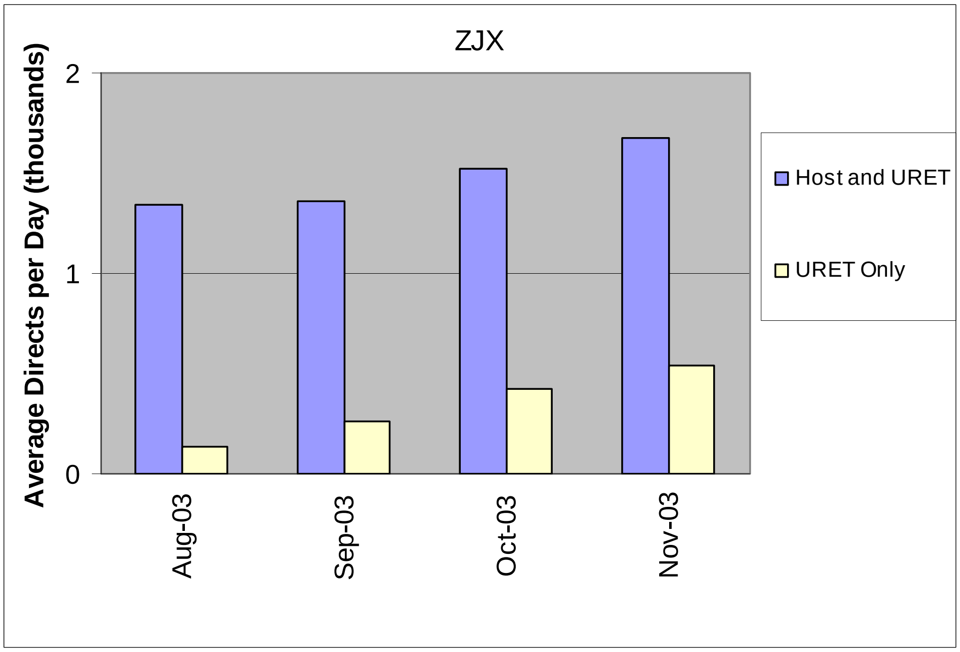

Figure 1. URET directs as a subset of total directs at ZJX

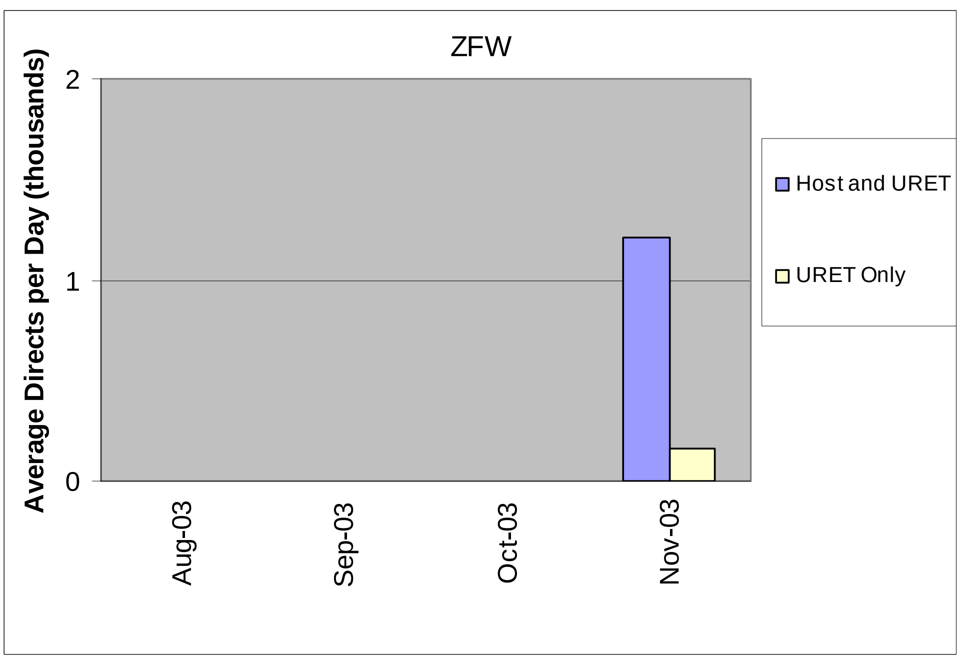

Figure 2. URET directs as a subset of total directs at ZFW

2.3 URET User Benefits

2.3.1 Metrics Used

The primary metrics that address URET benefits to NAS users are distance and time saved, static altitude restrictions lifted, and increased airspace capacity. A more complete description of the distance and altitude restriction metrics may be found in the FFP1 June 2001 report [4].

Several measures were employed to estimate the distance savings facilitated by URET. These measures include:

- Change in distance flown because of lateral amendments
- Change in average distance flown through each Center's airspace
- Change in distance flown for specific city pairs
- Change in time of flight for specific city pairs.

In addition to distance and time savings, there have been improvements in fuel efficiency resulting from the removal of altitude restrictions. The ZID and ZME Procedure and Benefits team was established to evaluate and, if appropriate, modify or remove altitude restrictions. As URET is deployed to more Centers, there is increased opportunity to eliminate inter-facility restrictions.

This report will focus on lateral amendment savings. Please refer to earlier reports ([1-9]) for information on other metrics.

2.3.2 Lateral Amendments

Lateral flight plan amendments are defined as those that change the direction of an aircraft but not necessarily its altitude. They include increases (e.g., turns to avoid congestion or heavy weather areas) as well as decreases in distance. The distance saved metric captures the average of the daily sum of distance changes resulting from lateral amendments. (These "savings" could be negative, indicating an increase in the distance flown.) The data include *all* lateral amendments entered into the Host for the specified time, not just URET amendments. Figure 3 shows the average distance savings per day from lateral amendments at ZID, ZME, ZKC, ZOB, ZAU, ZDC, ZJX, and ZFW between August 2002 and November 2003 as provided by Lockheed-Martin from production versions of URET.

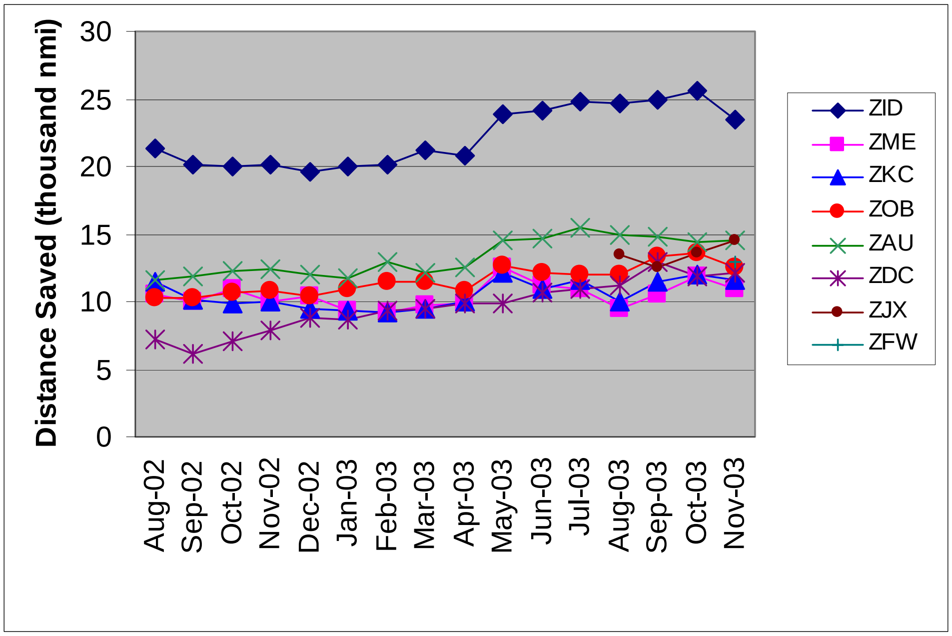

Figure 3. Lockheed-Martin Distance Saved

Note that the values for ZID are substantially higher than those for the other Centers. However, this difference is not the result of differing traffic levels, as ZOB, ZAU, and ZDC all have more flights per day than ZID.

Note also the apparent jump in the distance saved between April and May 2003 at ZID, ZME, ZKC, ZOB, and ZAU. The URET software was upgraded from version 1.6 to 2.1 at these centers in May 2003. ZDC was not upgraded until August 2003, and correspondingly there was no increase in distance saved in May of the same year. The URET 2.1 software provided additional functionality to the controllers, notably an APR (Air Traffic Control Preferred Route) list, which may have led to an increase in the number and length of directs. However, improvements to the trajectory modeler and other components also contributed to the apparent increase in the measured distance saved data, and these data collection modifications mask the effect of the additional functionality.

The distance saved metric does not indicate the net benefit of URET to NAS users. To calculate this net URET benefit, one would need to compare the URET distance savings with the baseline case (i.e., what the distance saved would be without URET). Often the lateral savings before URET deployment is used as a proxy for this non-URET value. However, Lockheed-Martin did not begin collecting data until August 2002, which was after IDU at the then-existing URET sites, while at ZJX, ZFW, and ZMP data acquisition began at IDU. In the absence of a means to directly calculate the distance saved from archived data sources, such as the Office of Air Traffic Airspace Management (ATA)

Laboratory's Enhanced Traffic Management System (ETMS) database, one must use indirect methods to infer the savings.

One way to approach the problem is to find a measure that increases along with lateral savings. The increase in distance saved combines contributions from two possible sources: a change in the number of amendments and a change in the distance saved per amendment. In the FFP June 2003 Report [8], the number of amendments was shown to be a good proxy for the distance saved because the distance saved per amendment did not vary much with time, and was approximately the same across Centers. The distance saved per amendment is plotted versus time in Figure 4 for all Centers since August 2002, or IDU date, whichever was later. Figure 4 shows that the distance saved per amendment is still a constant approximately equal to 4.5 nmi/amendment.

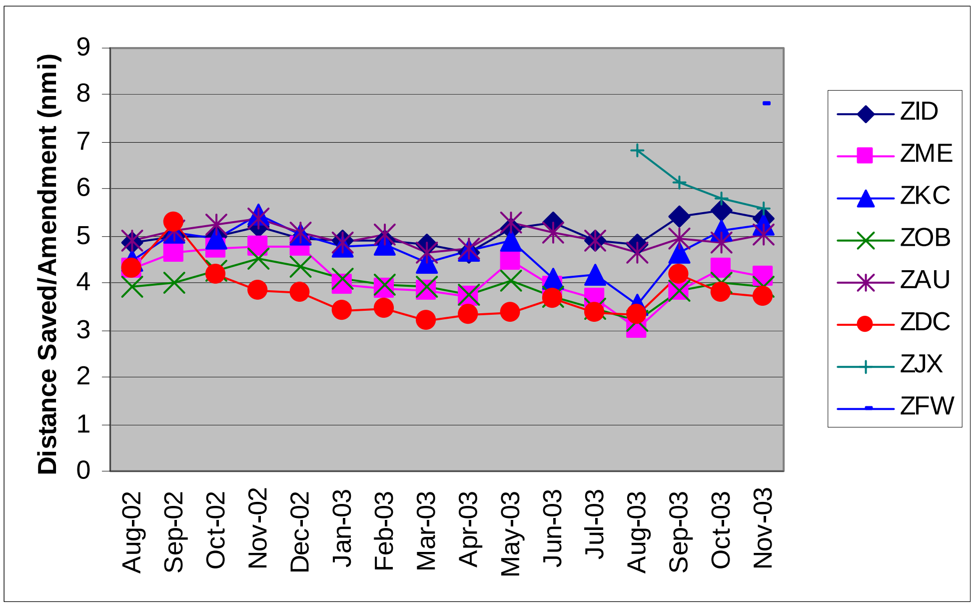

Figure 4. Distance Saved per Amendment

Figure 5 shows the monthly average number of amendments per day at ZID for January 1998 through November 2003, where the vertical line indicates the introduction of URET. The number of amendments has steadily increased, but another interesting aspect of the data is that there is a pronounced regular variation in the data, with a period of one year. One can correct for this effect by creating a seasonality factor. (See, for example, [10]) To create this factor, one creates a rolling average of the number of amendments centered on the month to be evaluated. For example, the rolling average for July 2002 would be: ((Sum of February 2002 to December 2002 Values)*2 + January 2002 Value + January 2003 Value)/24. The correction factor for July 2002 would be the rolling average for that month divided by the number of amendments in July 2002. The correction factors are averaged over the years for which they are available to produce a single correction for July of every year: July factor = Average(July 1998 factor, July 1999 factor, etc.). Finally, the correction factors are normalized so that they sum to 12.

Figure 6 shows that seasonally adjusted daily average number of amendments at ZID for the same time period shown in Figure 5. One can see that the seasonal variation apparent before the correction has been nearly eliminated, so that the overall trend in the data can be seen more clearly.

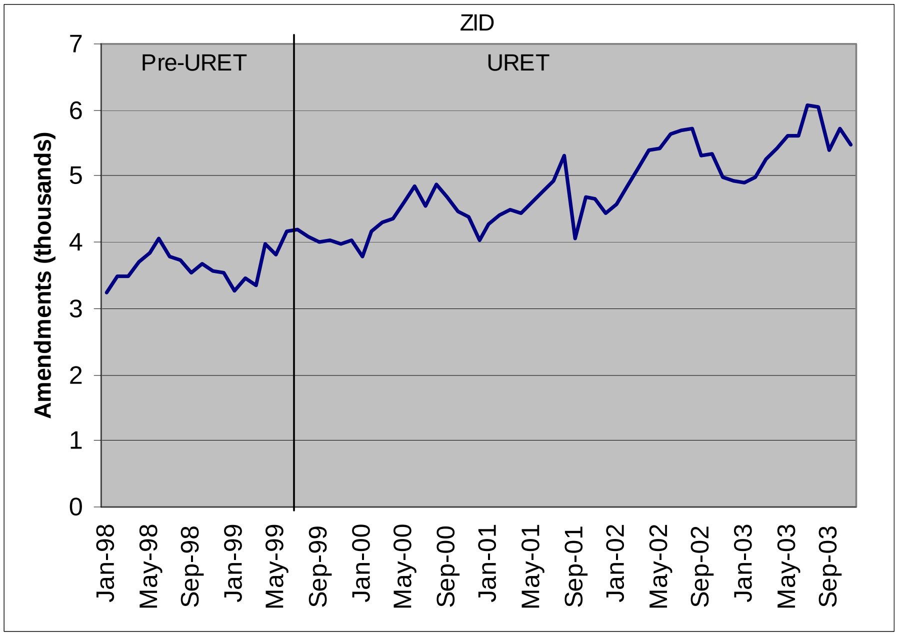

Figure 5. ZID Amendments

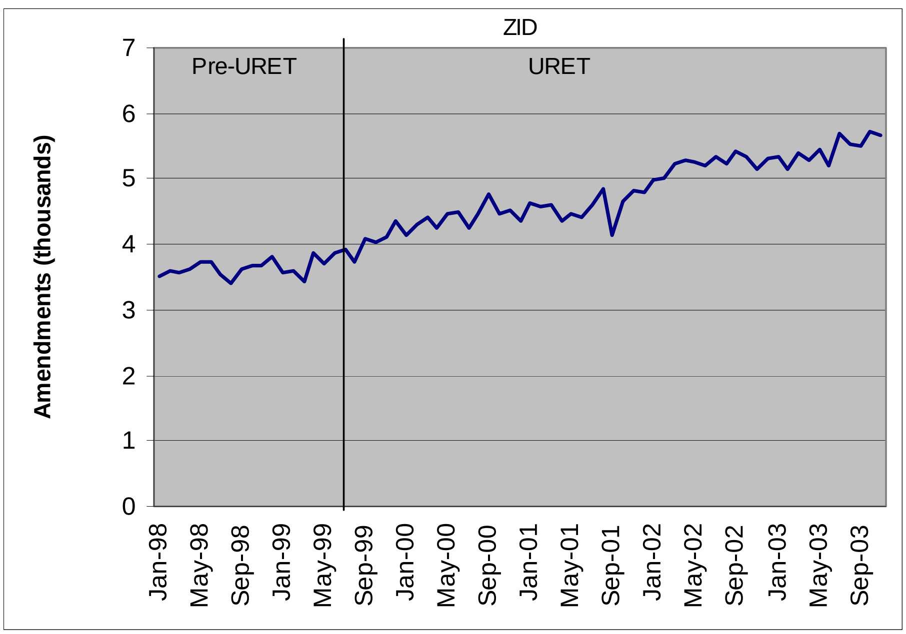

Figure 6. Seasonally Adjusted ZID Amendments

Figures 7 to 14 show the monthly average number of amendments per day for the other 8 URET Centers, based on ETMS data. We can estimate the increase in the number of amendments after deployment for each Center by comparing the average of the most recent (post-URET) months to the average level for the year prior to URET deployment. The distance saved was determined from the number of amendments using a conversion factor of 4.5 nautical miles per amendment, and the results are shown in Table 3. The estimated distance saved for all URET Centers combined is nearly 38,000 nautical miles per day, or $8.1 million per month.

Table 3. Amendments per Day Increase

ARTCC	Baseline	Increase after URET	Distance Saved per Day (nmi)
ZID	3647	2020	9088
ZME	2272	1189	5350
ZKC	2425	835	3757
ZOB	3885	615	2768
ZAU	3314	970	4364
ZDC	2934	1782	8019
ZJX	2832	751	3378
ZFW	2227	256	1151

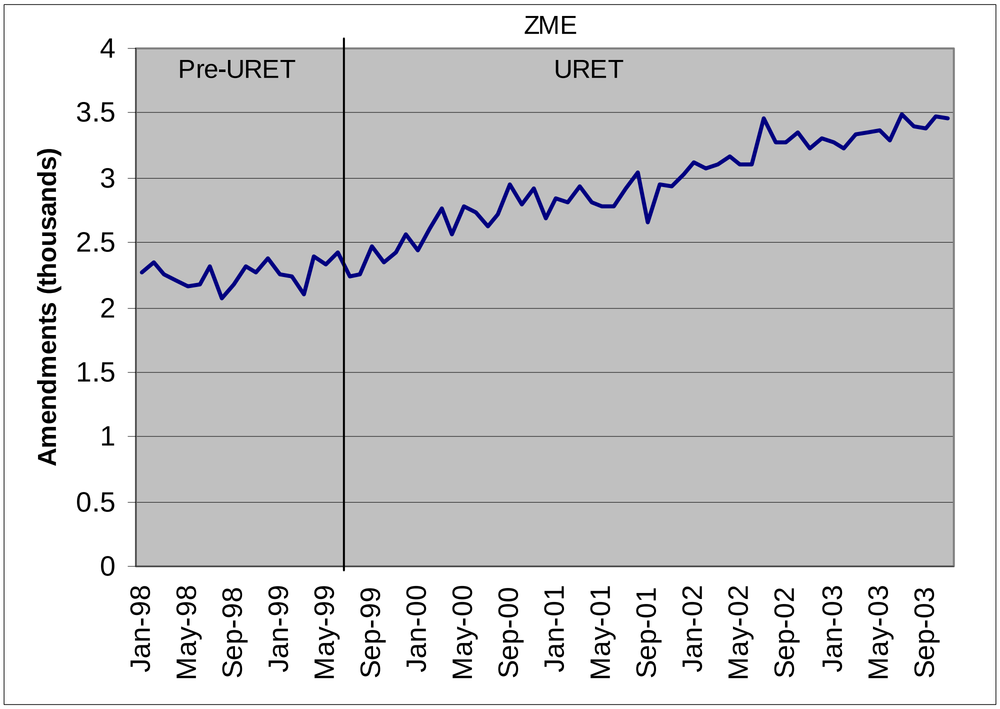

Figure 7. Seasonally Adjusted ZME Amendments

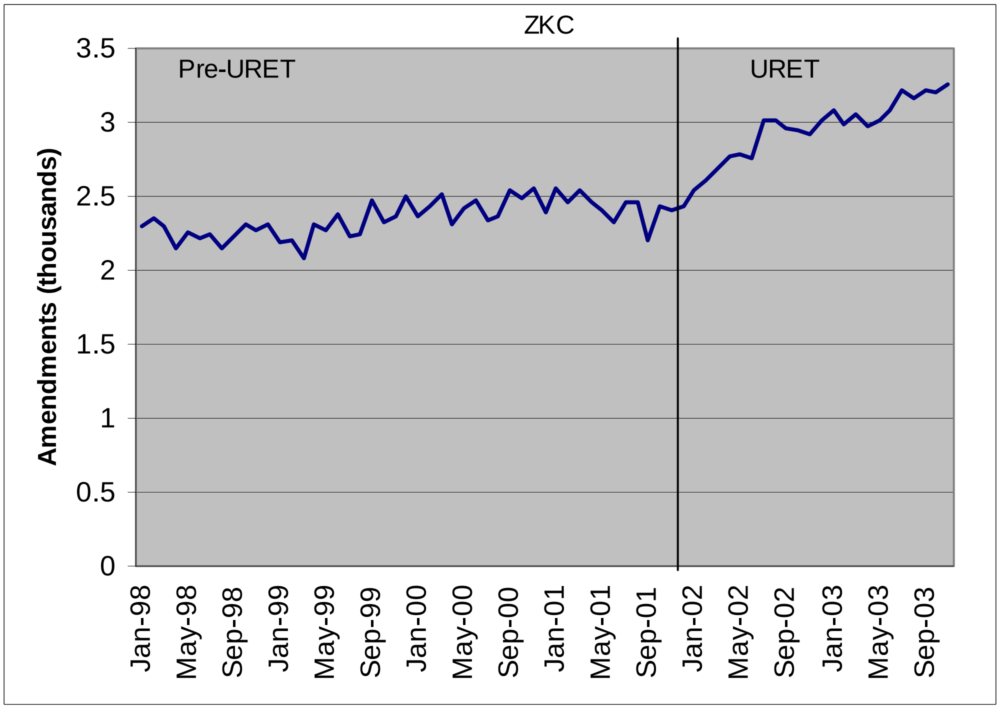

Figure 8. Seasonally Adjusted ZKC Amendments

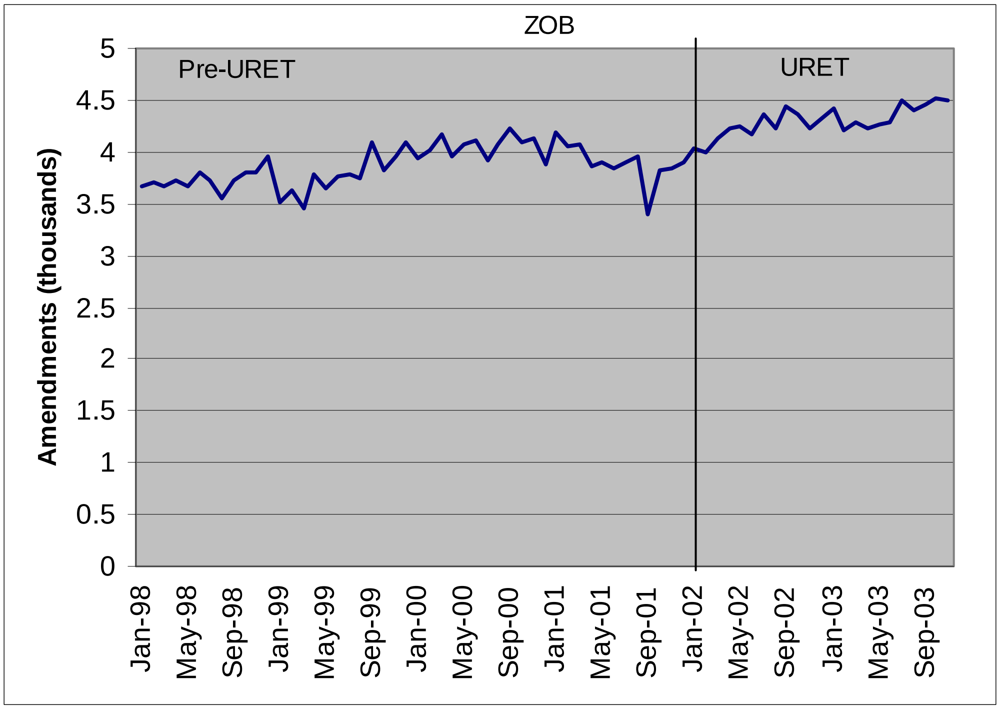

Figure 9. Seasonally Adjusted ZOB Amendments

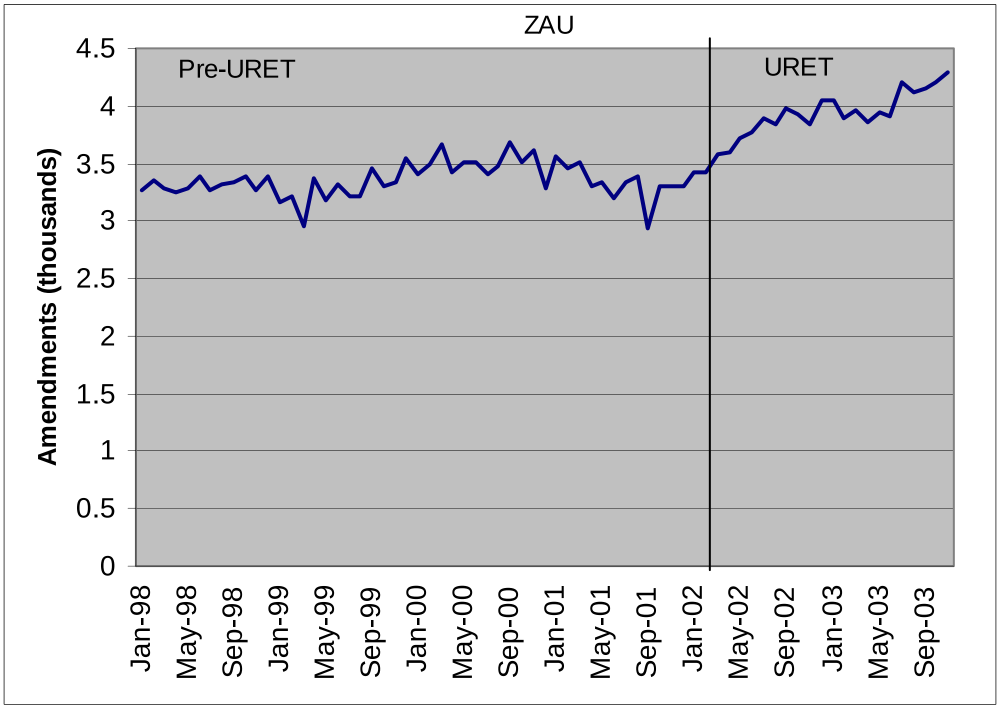

Figure 10. Seasonally Adjusted ZAU Amendments

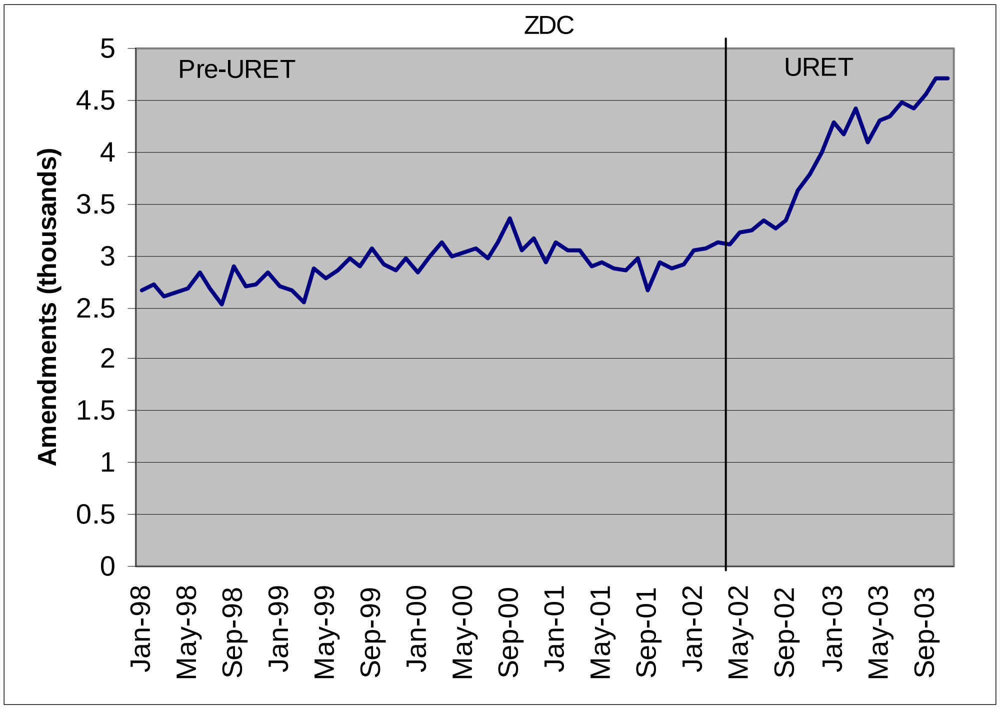

Figure 11. Seasonally Adjusted ZDC Amendments

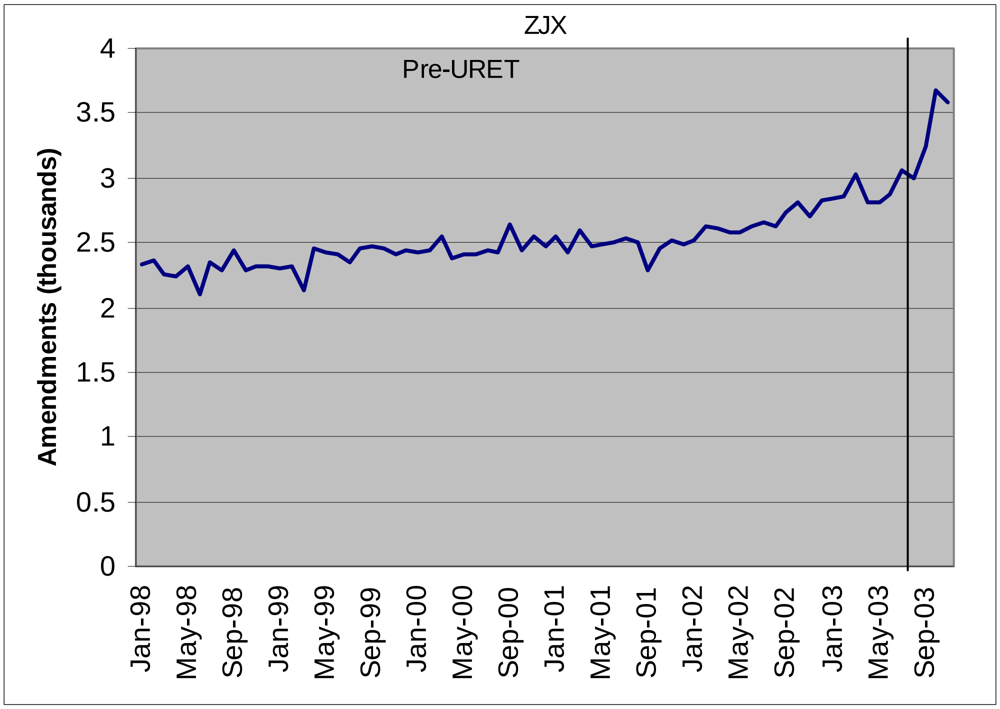

Figure 12. Seasonally Adjusted ZJX Amendments

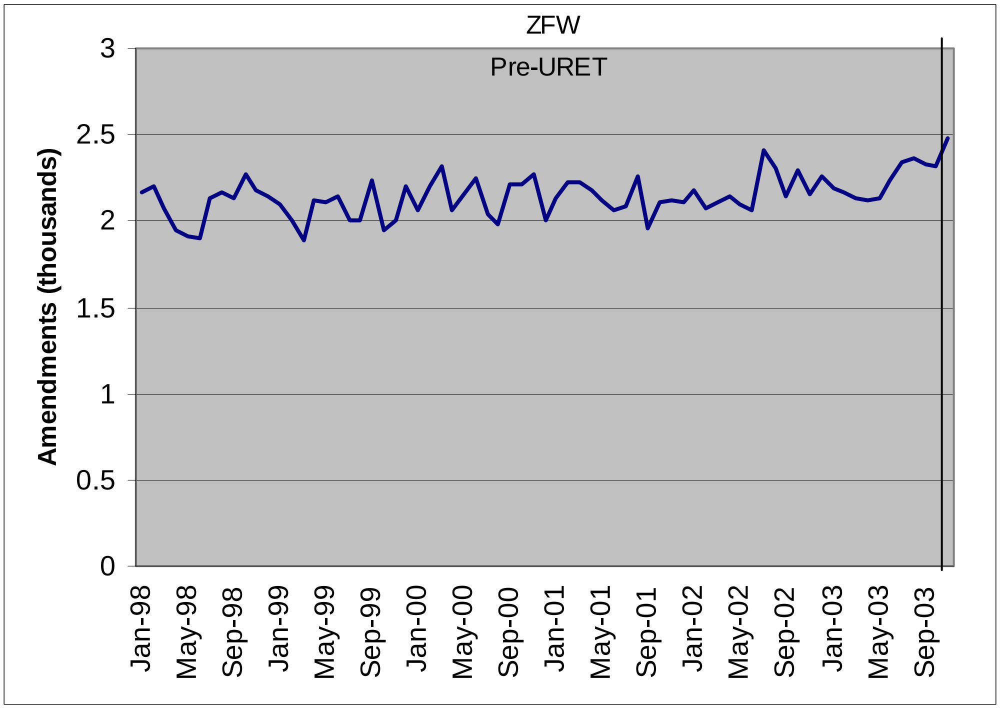

Figure 13. Seasonally Adjusted ZFW Amendments

3.0 TRAFFIC MANAGEMENT ADVISOR (TMA)

TMA currently operates at eight ARTCCs. (Table 4 lists the deployed sites.) At each ARTCC, TMA computes arrival schedules for a specific airport. At Los Angeles Center (ZLA), Atlanta Center (ZTL), and Houston Center (ZHU), the TMA system also includes an Adjacent Center Data Feed (ACDF), which allows for more coordination for flights in an adjoining center's airspace. This section describes the operational use of TMA, summarizes the benefits to date at all ARTCCs, outlines the methodologies used in recent measurements of benefits, and presents results of the benefits analyses. More specifically, the results include:

- A study of gate and airborne delays of Oakland Center (ZOA) departures to Los Angeles Airport (LAX) after ACDF
- The effect of Miles-In-Trail (MIT) restrictions at LAX during times of low demand
- Two studies that compare Time Based Metering (TBM) and MIT restrictions in ZLA.

We also consider restrictions between Memphis Center (ZME) and ZTL after the addition of ACDF data at ZTL.

Table 4. Deployed TMA Sites

ARTCC		Airport	
Name	**Identifier**	**Name**	**Identifier**
Fort Worth	ZFW	Dallas/Fort Worth International	DFW
Minneapolis	ZMP	Minneapolis-St. Paul International	MSP
Denver	ZDV	Denver International	DEN
Los Angeles	ZLA	Los Angeles International	LAX
Atlanta	ZTL	Wm. B. Hartsfield Atlanta International	ATL
Miami	ZMA	Miami International	MIA
Oakland	ZOA	San Francisco International	SFO
Houston	ZHU	George Bush Intercontinental	IAH

3.1 Description

TMA assists controllers with arrival aircraft in the en route cruise and transition airspace managed by ARTCCs. TMA provides ARTCC personnel with a means of optimizing the arrival throughput of capacity-constrained airports, thereby reducing delay. The resulting uniformity of arrival flows can also lead to an increase in departure rates and a decrease in departure delays.

Inputs to the TMA system include real-time radar track data, flight plan data, and a three-dimensional grid of wind speeds and directions. TMA trajectory models use this information, updated every 12 seconds, to optimize schedules to the meter fixes for all arriving aircraft that have filed Instrument Flight Rules (IFR) flight plans, with consideration given to separation, airspace, and airport constraints. These optimized schedules may then be displayed on controller radar displays, and used to ensure a smooth, efficient, and safe flow of aircraft to the terminal area.

3.2 Summary of Previous TMA Results

In previous documents, we reported the operational benefits of TMA. We found TMA increases arrival throughput and thereby reduces arrival delays. At some airports with shared runways, overall operations rates increased (arrivals plus departures) during arrival peaks. When used by traffic managers as a planning tool, TMA reduced holding, flight times, and departure delay for aircraft departing airports within the ARTCC en route to the TMA-adapted airport (so-called “internal departures”). We summarize previous results for TMA sites in Table 5. The paragraphs following Table 5 provide more details on the analyses at each site.

Table 5. Changes in metrics following TMA introduction at FFP1 sites

	Center/Airport						
Metric	ZFW/DFW	ZMP/MSP	ZDV/DEN	ZLA/LAX	ZTL/ATL[1]	ZMA/MIA[1]	ZOA/SFO[1]
AAR	+5%	+0.7/hr vis, (+1.2%) +1.4/hr inst (+2.6%)		+1/hr inst (+1.5%)	+2/hr (+2.5%)		
Peak Arrival Rate			+1/hr vis, (+1.8%) +2/hr inst (+4.1%)	After TMA +1.7/hr (+3%) Additional After TBM +2/hr inst (+5% inst)	+3.6/hr vis (+3.9%) +2/hr inst (+2.5%)		
Peak Ops. Rate		+4/hr vis, (+3.8%) +5/hr inst (+5.0%)					
Arrival Delay	-70 sec						
Airborne + Gate Delay, internal departures				After TMA -4.0 min (-34%) Additional after TBM -1.4 min (-23%)	-4.0 min (-25%)	-6.0 min (-46%)	-6.2 min (-35%)
Extended Terminal area Flight Distance		-5 nmi vis, -9 nmi inst				-6 nmi	-2.5 nmi
Extended Terminal Area Flight time						-1.1 min East config, +0.25 min West config	-.2 to -.3 min
Delay Distribution[2]		-2%					
Holding				-12%[3]	-24%[4] -9%[5]		
Restriction value[6]				-24% for LAX arrivals from ZOA			

[1]Not currently using time-based metering capability
[2]Percentage of flight distance from 160 nmi to runway that is within the TRACON
[3]Total holding pattern circuits
[4]Total holding time Jun-Jul 2000 vs. Jun-Jul 2002
[5]Total holding time Jan-Apr 2002 vs. Jan-Apr 2003
[6]Restriction value = Miles-in-Trail value X length of time restriction in place

ZFW was the first TMA implementation site. ZFW began TMA operations before the establishment of the Free Flight program, concurrent with the redesign of DFW terminal airspace. The National Aeronautics and Space Administration (NASA) Ames Research Center analyzed the impact of TMA at ZFW [11], finding a reduction in delay of 70 seconds per arriving aircraft during periods when demand exceeded capacity. Additionally, they found that the Terminal Radar Approach Control (TRACON) increased the Airport Acceptance Rate (AAR) by 5 percent.

At ZMP, the Traffic Management Unit (TMU) uses TMA as a strategic planning tool and controllers use TMA for tactical time-based metering (TBM). Initial Daily Use (IDU) of TMA for MSP arrivals began in June 2000. We reported measured increases in actual operations rates at MSP of 4 and 5 operations per hour (4 to 5% percent increase) under visual and instrument conditions, respectively [5]. Initially, we found no discernible change in the AAR at MSP. However, after MSP TRACON traffic managers were given TMA displays, the AAR increased by 0.7 (visual) and 1.4 (instrument) arrivals per hour [6]. As further evidence of benefit, an examination of flight distances in the terminal area showed decreases of 5 nmi (visual) and 9 nmi (instrument), and a redistribution of delay to higher, more fuel-efficient altitudes [5].

TMA daily use at Denver Center (ZDV) for DEN arrivals began in September 2000. While DEN has excess capacity at most times, there are times during poor weather where demand exceeds capacity and delays accrue. An assessment of TMA during these times found that the tool increased arrival rates by 1 (visual) to 2 (instrument) aircraft per hour (2 to 4 percent increase) [5]. Most of the time, air traffic managers use TMA to make strategic decisions about MIT restrictions. We expect that benefits from TMA will increase at ZDV/DEN as demand increases.

Active use of TMA started at ZLA for arrivals to LAX in June 2001. Initially, ZLA traffic managers used TMA as a strategic tool to determine the necessity of location-based MIT restrictions. Controllers at ZLA began testing TMA for time-based metering of arrivals in May 2002. Initial studies focused on the use of the tool by traffic managers for planning and management. Reference [6] reported a 3% increase in actual arrival rates, and a small (1.5%) increase in AAR during instrument conditions. Reference [5] also reported a 12% decrease in holding for arrivals, and a 34% decrease in combined gate and airborne delay for internal departures. Soon after ZLA started TBM, we found a further 5% increase in arrival rates during instrument conditions [7]. Most recently [8], we reexamined internal departure delays to LAX, finding an additional 23% decrease in combined gate and airborne delays. We also began examination of MIT restrictions inside ZOA airspace for flights entering ZLA airspace. After TBM at ZLA, the number of MIT restrictions and the length of time they were active decreased. To measure both of these effects, we developed a restriction value metric[1] that decreased by 24% after TBM. Also in May 2003, ZLA began to receive an Adjacent Center Data Feed from the ZOA TMA system. ZLA uses this feed to better handle traffic from ZOA airspace including the setting of restrictions between the ARTCCs.

Traffic managers began to use TMA at ZTL for ATL arrivals in June 2001. ZTL has not yet implemented time-based metering. However, in January 2003 ZTL required mandatory usage of TMA as the primary data source for the strategic planning of restrictions. Even before mandatory usage, we found a 24% reduction in total holding time when we compared June-August 2000 with the summer months of 2002 [7]. We

[1] The metric is the product of the restriction severity (e.g. number of miles for MIT) and the length of time the restriction was in effect. For example, a 10 MIT restriction in place for 30 minutes would have a restriction value of (10x30)=300.

also found a 25% reduction in combined airborne and gate delay for internal departures [6]. Focusing on the specific effect of mandatory usage of TMA, we found a 9% reduction in total holding time from January-April 2002 compared with the same period in 2003 [8]. Comparing the 4 months before to the 4 months after mandatory usage of TMA, we also estimated a 2.5% increase in the acceptance rate and increases in the actual arrival rate for both visual (+3.6%) and instrument (+2.5%) conditions [8].

TMA became operational at Miami Center (ZMA) for MIA arrivals in May 2001. The TMU is using TMA as an aid in decision-making and strategic planning. TMA displays are also operational at the MIA TRACON, where the TMU uses the system load graph to help make decisions about airport configuration, restrictions, and staffing. ZMA has not yet fully implemented time-based metering, although they did tests of TBM during 2003. After initial implementation, we reported a 6 nmi. decrease in flight distance in the terminal area during peak arrival periods [7]. We also examined a reduction in the flight distance variance, corresponding to increases in predictability. Further, we found a 46% decrease in combined gate and airborne delay for internal departures. In our June 2003 report [8], we examined the initial tests of TBM at ZMA. We found that while there was not enough data for a statistically significant result, the few days of data suggested an increase in the peak arrival rate.

ZOA began TMA use for SFO arrivals in August 2001. ZOA has not yet implemented time-based metering due to numerous pending airspace changes associated with the new Northern California TRACON. Nevertheless, ZOA traffic managers are using TMA to help manage flows into SFO much like what was described above at ZTL and ZMA. After initial implementation, we reported 2.5 nmi decrease in flight distance in the terminal area during peak arrival periods [7]. Further, we found a 35% decrease in combined gate and airborne delay for internal departures.

The most recent site to receive TMA is ZHU for IAH arrivals. They began operation in June 2003. TBM tests are being conducted at the time of this writing. In this document we further explore benefits of TMA at ZHU.

Although holding has not been completely eliminated with TMA and time-based metering, centers report that shared situational awareness enabled by TMA has eliminated "no-notice" holding.

3.3 TMA at ZLA/LAX

ZLA began daily use of TMA in June of 2001. Initially, ZLA used TMA as a strategic tool for traffic managers, but did not use the list that allows tactical TBM by individual controllers. Personnel at ZLA conducted an operational suitability assessment of TBM with TMA between May and July 2002. They continued additional operational testing in August and September 2002, and began mandatory TBM usage in November 2002 between 9:00 AM and 12:00 PM, Monday through Friday. In May 2003, ZLA began to receive an Adjacent Center Data Feed (ACDF) from the ZOA TMA system. ZLA uses this feed to better handle traffic from ZOA airspace including the setting of restrictions between the ARTCCs. In the following sections we examine the benefits of TMA and Adjacent Center Data Feed.

3.3.1 Departures from ZOA to LAX

One of the features of the ACDF is the ability of ZLA to use TMA to better manage ZOA departures headed for LAX. This added control allows the TMU the ability to optimize the timing of these flights into the arrival stream, thereby preventing delays. This is similar to the benefit for LAX arrivals from ZLA internal departures, which is described in our past reports.

We use a pre-ACDF period from May – October 2002 and a post-ACDF period of May – October 2003. We also examine two measurements of delay for both gate and airborne times. Delays are normally defined as the positive difference between the actual time and the scheduled time for an event. Negative differences represent times when the flight is early. Usually, early flights are treated as having zero delay, regardless of how early they arrive. However, we had heard that after ACDF many flights from ZOA to LAX are arriving before their scheduled times. Thus, we decided to examine the usual delay values, and in addition, we include negative values for early flights.

Figure 14 displays gate delay and Figure 15 displays airborne delay for ZOA departures to LAX before and after ACDF. The gate delay shows a 47 sec (11%) decrease after ACDF, while the gate delay counting early flights shows a 1 min 52 sec (39%) decrease. This difference in results suggests that quite a few flights are departing earlier than scheduled. The airborne delay decreases by approximately 48% for both methods of calculating delay.

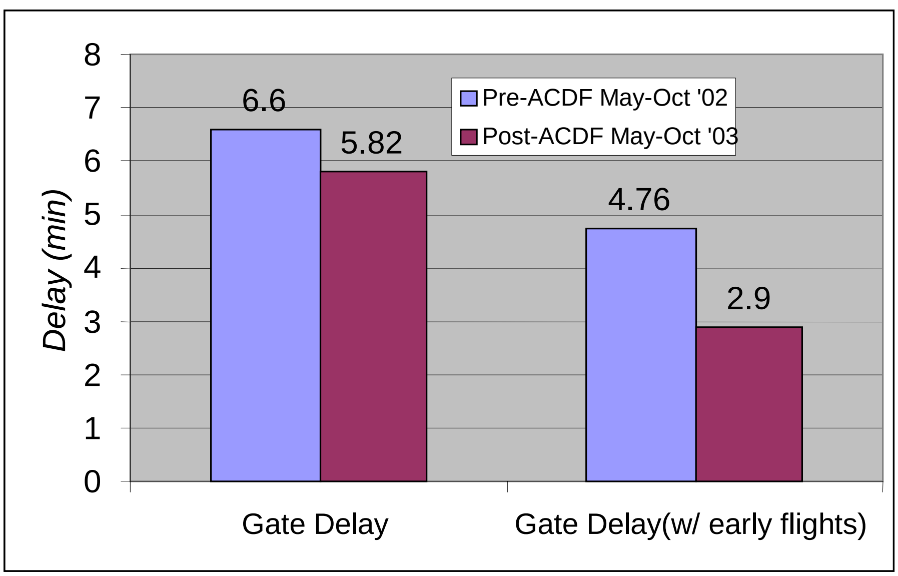

Figure 14. Gate delays for ZOA departures to LAX

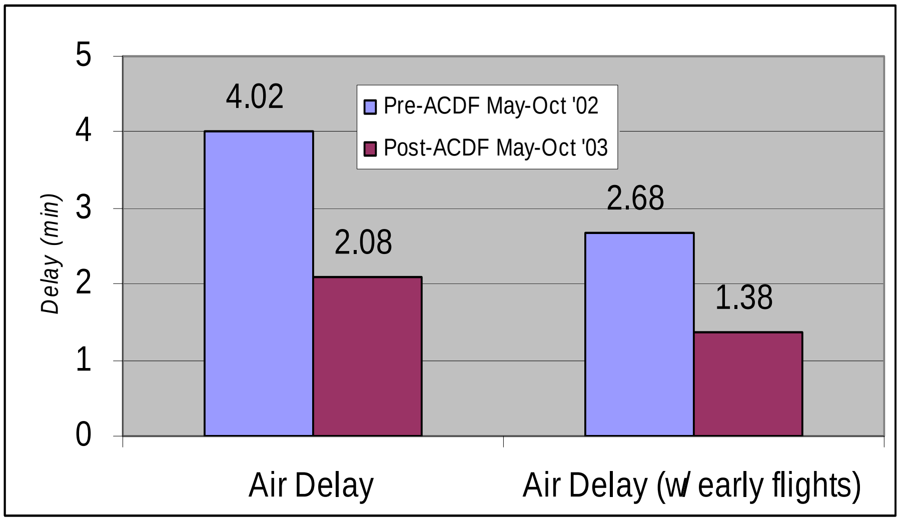

Figure 15. Airborne delays for ZOA departures to LAX

To see if the delay changes were part of a trend for all arrivals into LAX, we considered gate and airborne delay for LAX arrivals from all US airports. Using the same periods used in the ZOA departure case, we found that on average, the gate and airborne delay did not decrease, but increased by a few seconds for both gate and airborne delay. This fact supports the conclusion that ACDF use by ZLA was the main driver for the delay decreases among ZOA departures to LAX.

3.3.2 MIT at LAX

In the June 2003 Metrics Report [8], we examined the reduction in restrictions on LAX arrivals from ZOA. We attributed the 24% reduction in restriction value to the use of ACDF by ZLA. One of the claims of TBM and ACDF is that MIT restrictions can unnecessarily starve the runway, in which case the actual arrival rate would be less than the demand, even during times when the demand is less than the airport capacity (AAR). We decided to confirm this by examining the difference in the arrival demand and actual arrivals at LAX during times with ZOA MIT restrictions to LAX. We also limited the analysis to those times when the arrival demand was less than the AAR. Note that we are examining the effects on the total arrival rate, not just traffic from ZOA. We want to focus on the total airport effects of ZOA restrictions. We used Aviation System Performance Metrics (ASPM) reported 15 minute bins of arrival demand and actual arrivals, and restriction times from ZOA logs. Since it takes some time for restricted planes to arrive at the runway, we lag the runway information by 15 minutes to allow time for the restriction to affect the arrival rates. The time period examined was May 2002 – October 2003.

Figure 16 displays the mean difference between demand and actual arrivals in 15 minute bins when different restrictions are in place. It only examines times when the airport is **not** capacity constrained (Demand < AAR). The mean difference values are quite small, indicating that on average LAX meets its demand when the demand is less than the airport capacity. However, there is an upward trend with increasing MIT restrictions.

This indicates that MIT restrictions do lead to inefficiencies in meeting the demand during times when the demand is lower than capacity. Decreases in the use of MIT restrictions, or more judicious or timely use of these restrictions using TBM and/or ACDF, should allow the airport to better meet the demand.

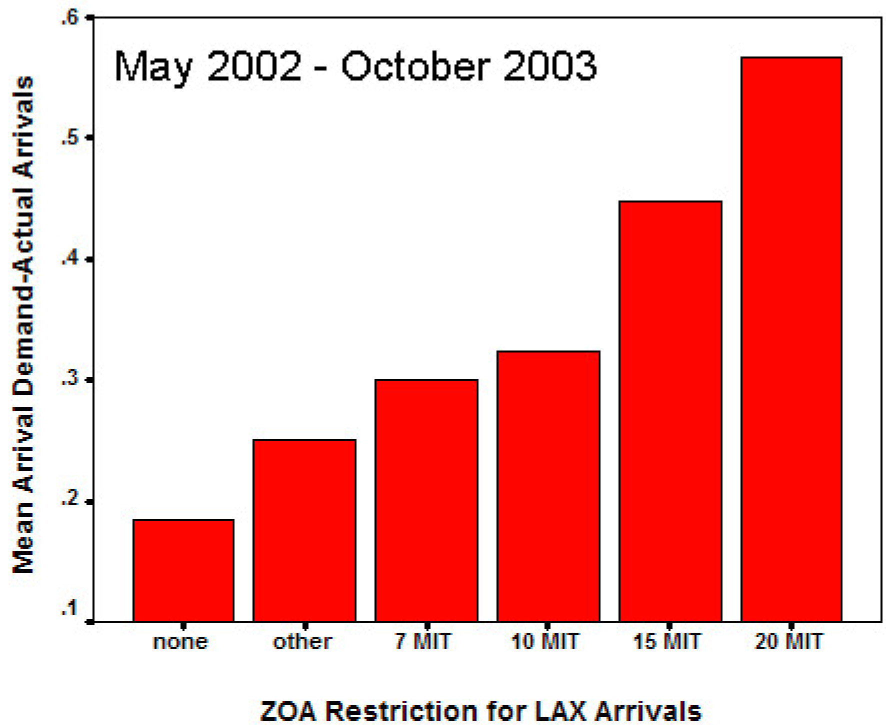

Figure 16. Arrival Demand – Actual Arrivals for different restrictions when Demand < AAR

3.3.3 NASA and SCT TBM studies

In addition to the Free Flight Program Office, the FAA and NASA also cooperate in measuring TMA benefits using the Performance Data Analysis and Reporting System (PDARS). PDARS is a joint FAA-NASA effort to monitor day-to-day operations of the National Airspace System (NAS) and to measure delivery of services by Air Traffic Control (ATC). Recently, both NASA and Southern California TRACON (SCT) presented evidence of the benefits of TBM found using PDARS.

The NASA study examined flight time and distance of LAX arrivals approaching through sectors 19 and 20 during periods of TBM and MIT. The data included detailed descent profiles of aircraft from two airlines over 7.5 hours of MIT and 7.5 hours of TBM. Flights during TBM averaged 38 seconds and 2.05 nmi less than flights during MIT. The result was statistically significant and supports claims of greater airport capacity during TBM. NASA also examined the descent profile differences and suggested that flights during TBM flew a more uniform path.

The SCT study also focused on the differences between MIT and TBM. The study assumed a usual MIT restriction for jet arrivals into SCT airspace of 10 nmi. When ZLA uses TBM, the system is configured to allow jet arrivals to enter at an effective minimum of 7 nmi. in trail. SCT searched for events where three consecutive aircraft entered with a spacing less than 20 nmi. Such events would indicate that the airspace operates more efficiently during TBM than it would during traditional MIT. They studied 10 days of data in September and October 2003. They found, on average, 8 reduced separation events per day during the study.

3.4 TMA at ZTL/ATL

Initial Daily Use of TMA at Atlanta Center began in February 2001. At the outset, traffic managers used the tool to increase their situational awareness. By June 2001, all traffic managers had been trained in the use of the tool and were using it for various management functions. ZTL has not yet implemented time-based metering. However, as of January 15, 2003, ZTL requires mandatory usage of TMA by Traffic Management Coordinators (TMC) as the primary data source for the strategic planning of restrictions. Also, in late September 2003, ZTL started receiving an Adjacent Center Data Feed from Memphis Center (ZME). This new information allows traffic mangers the ability to better judge the necessity of miles-in-trail restrictions at the ZME/ZTL boundary. Managers report that this new way of establishing restrictions has led to fewer instances of restrictions and/or less severe restrictions.

To test the positive impact reported by ZTL since the implementation of the TMA ACDF with ZME, we examined the number of miles-in-trail restrictions passed back to ZME for ATL arrivals. ZTL TMCs and other TMA personnel claimed that there had been a reduction in the restrictions issued to ZME for traffic flows proceeding over the Rome, GA navigational aid (RMG) and the DALAS meter fix. We used data collected from ZTL logs to verify and quantify this observation.

Based on ZTL input, the primary benefit we expected was a reduction in restrictions of 20 miles or greater. Our analysis showed an approximate 50% reduction in the fraction of restrictions that were 20 miles or greater (see Figure 17).

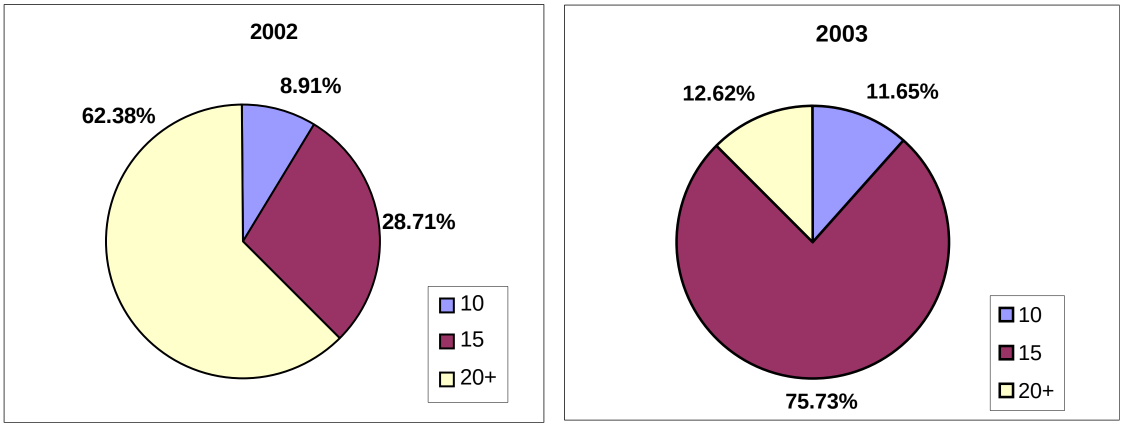

Figure 17. Miles-in-trail restrictions given to ZME from ZTL, Oct-Nov 2002 compared to 2003

Next, we factored in the duration of the restriction time for the periods used above. We computed a restriction "value" by multiplying the duration of the restriction by the number of miles-in-trail required. We then compared the total value for each time period. As indicated in the Figure 18, there is an approximate 22% decrease in this restriction value. Note that overall operations at ATL increased by about 7% over this time period, with a corresponding increase in capacity due to favorable weather conditions in 2003. This gives us confidence that we are looking at the system under comparable conditions.

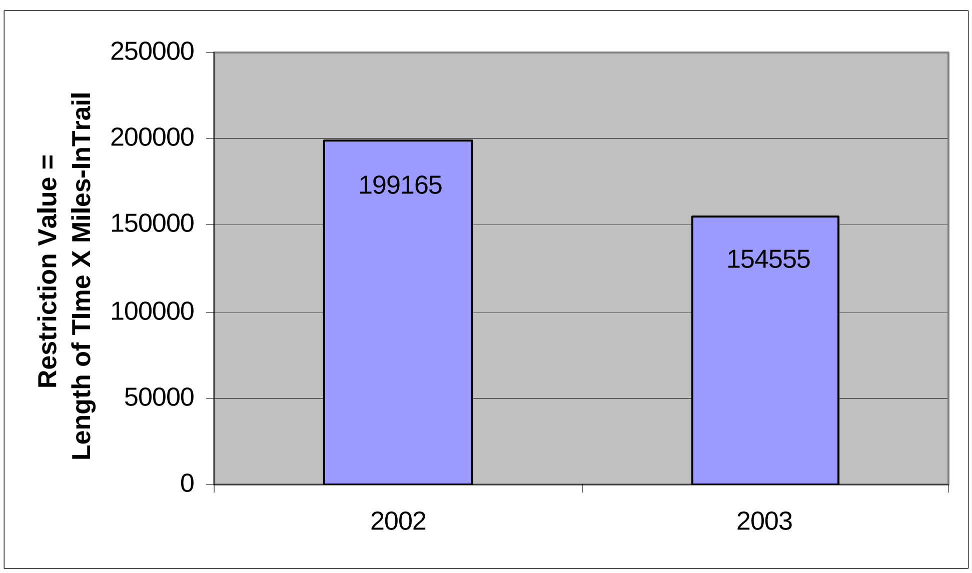

Figure 18. Restriction values for arrivals to ATL from ZME

4.0 COLLABORATIVE DECISION MAKING (CDM)

CDM is a joint government/industry initiative aimed at improving air traffic management through increased information exchange, procedural changes, tool development, and common situational awareness among the various parties in the aviation community. The program is one of the core technologies in the FAA's Free Flight program and includes participants from the FAA, aviation industry, and academia.

Previous Free Flight reports [2-8] have focused on several different areas within CDM. Some of the analytical findings include:

- A preliminary analysis of benefits from Slot Credit Substitution (SCS), a procedure designed to allow slot-by-slot substitution during a Ground Delay Program (GDP), indicated that the new functionality was being used successfully to enable utilization of landing slots that might previously have gone unfilled.
- A change in the compliance window for Estimated Departure Clearance Times (EDCTs) from –5/+15 minutes to –5/+5 minutes resulted in improved EDCT compliance and actual arrival times closer to scheduled arrival times.

In this report, we will focus on utilization metrics for the Flow Evaluation Area (FEA) capability in the Enhanced Traffic Management System (ETMS) and on recent benefits estimates for SCS functionality.

4.1 FEA Usage

As part of the Free Flight Phase 2 Program, functionality associated with the Collaborative Routing Coordination Tool (CRCT) was incorporated in ETMS. Included in this functionality is the ability to define Flow Evaluation Areas (FEA). An FEA is a three-dimensional volume of airspace, along with a specified time interval and flight filters (to specify specific traffic flows, if desired), that can be used to identify flights subject to a potential traffic flow constraint.[2]

By creating an FEA, Traffic Management Controllers (TMC) can evaluate the impact of potential flow constraints, such as forecast severe weather, anticipated high traffic levels, etc. FEAs may be:

- Private—for use by the generating TMC only
- Shared—available to selected system stakeholders, e.g. TMUs in adjacent centers
- Public—available to all system stakeholders.

In the case of public FEAs, a dynamic flight list provides real-time data on affected flights to the airlines, increasing their ability to plan a reroute.

[2] FEA functionality is similar to Flow Constrained Area (FCA) functionality. While an FEA is used to evaluate a *potential* constraint, FCAs are used in the generation of reroute advisories associated with an identified actual traffic flow constraint.

MITRE/CAASD developed a questionnaire to gain some insight into how the facilities utilize the FEA capability. Some facilities, e.g. ZOB, use multiple FEAs routinely as part of the traffic monitoring process. Other FEA usage is more event-driven, responding to severe weather or other potential traffic constraints. An example is shown in Figure 19, where a public FEA was constructed to evaluate traffic in the vicinity of forecast thunderstorms in ZKC. Since the FEA is public, it is available on the Common Constraint Situation Display (CCSD), and airlines can determine if any of their flights could be affected. Rerouting around the potential problem is left to the discretion of the airlines, using User-Preferred Trajectories (UPT). Thus, the use of a public FEA allows CDM participants to work together to resolve a potential problem.

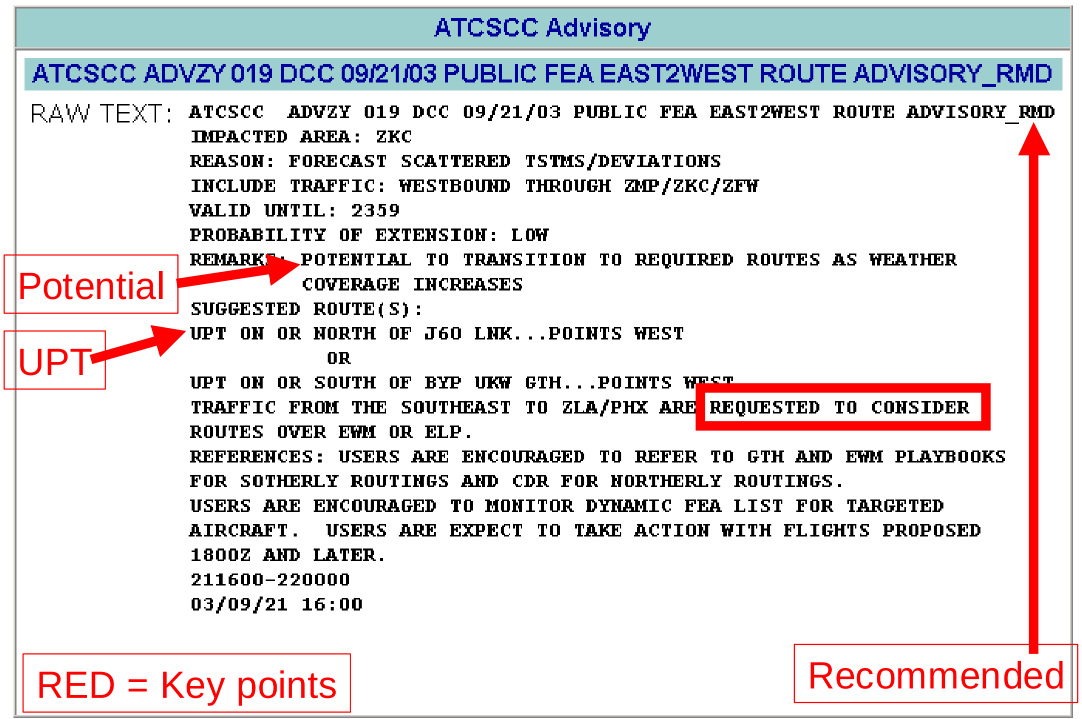

Figure 19. ATCSCC Adivisory for a Public FEA

FEAs are also used to assess the need for miles in trail restrictions (MIT), enabling the tuning of MIT restrictions to more accurately capture what is actually needed. MIT restrictions have been reduced and even cancelled as a result of the use of FEAs. For example, on August 15, 2003, an MIT restriction was cancelled for flights from Boston Center (ZBW) entering New York Center (ZNY) on the information provided by the FEA that there were no flights expected from ZOB that would need to merge with the ZBW flights. In an excerpt from a questionnaire of controllers at ZOB, one respondent wrote: "The FEA has fine-tuned our restriction process. One specific benefit is a better analysis of exactly when a restriction is needed or not needed on 2 competing lines of traffic."

Since August 2003, the Air Traffic Control System Command Center (ATCSCC) Operations Team has tracked the number of FEAs created as part of an effort to monitor and assess the usage of the tool. Figure 20 shows the cumulative number of FEAs created NAS-wide since the tracking began.

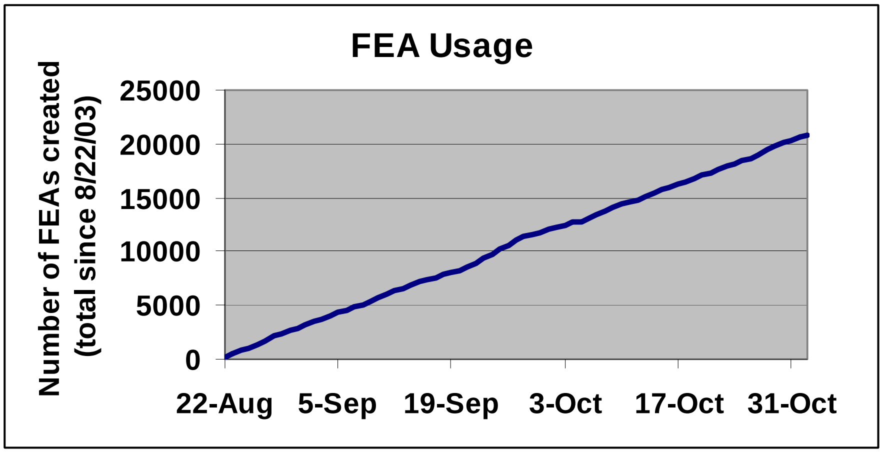

Figure 20. Cumulative sum of FEAs created over the full NAS

4.2 Slot Credit Substitution (SCS) Benefits

SCS is a procedure designed to allow slot-by-slot substitution of aircraft into vacated slots during a GDP. Prior to SCS implementation in May 2003, the rules of airline substitution during a GDP, referred to as "simplified subs," only allowed intra-airline substitution. If, for example, an airline cancelled a flight, the airline still "held" that slot, and only that airline could substitute into that slot. If the airline did not have another flight that could arrive during that GDP slot, the slot may have gone unused, wasting airport capacity. With SCS, an airline can relinquish that earlier arrival slot to other users in exchange for a slot at a later time. Flights from other participating airlines are used to bridge the gap between the slot given up and the later slot. SCS functionality was described in more detail in [8].

At the November meeting of CDM participants in Seattle, WA, the ATCSCC Quality Assurance department described a recent analysis of SCS benefits. We summarize the analysis here; the full report is available at [13]. This analysis updates and expands a preliminary assessment of SCS utilization reported in [8].

The current analysis covers a two-week period, October 6-21, 2003. All GDP programs in the NAS during that period were analyzed, comprising over 4800 controlled flights (i.e. flights affected by the GDPs). All instances of SCS activity during these GDPs were reconstructed. Reconstruction of a SCS substitution requires tracking of several different types of messages, including Bridging messages (BRG), EDCT Change Request (ECR) and SCS messages, and following the chain of events in the SCS event by associating these messages with changes in EDCTs in the EDCT Log. Figure 21 below shows the usage of these messages types at various airports compared to the number of GDP controlled flights.

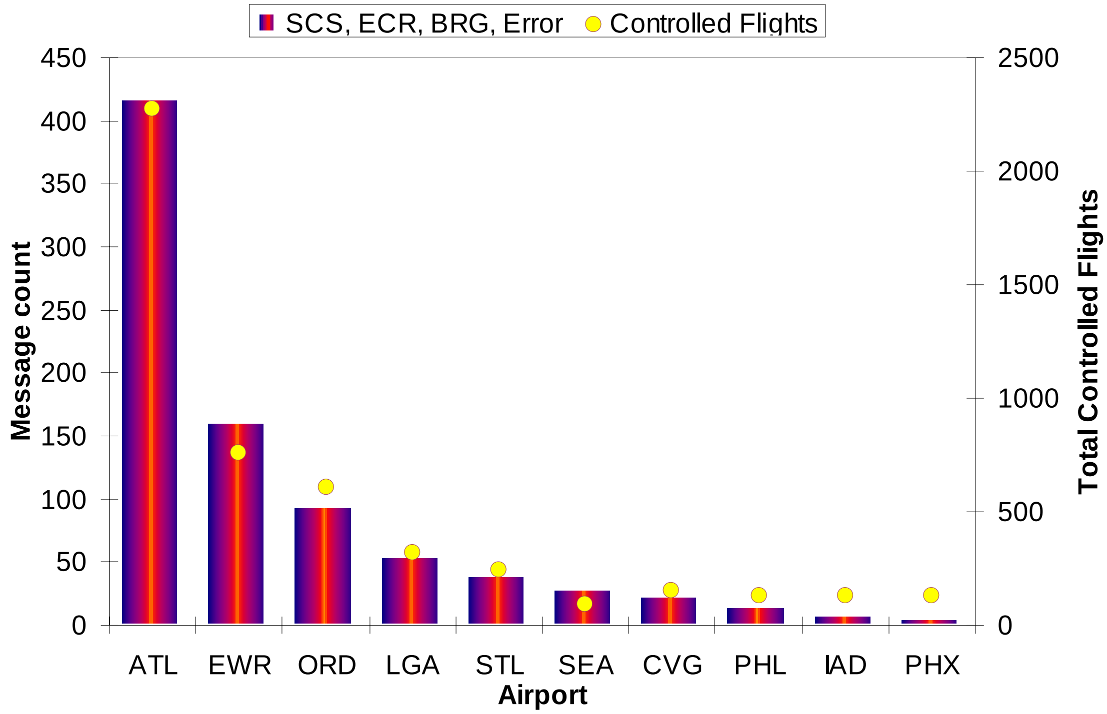

Figure 21. Message count for SCS activity and controlled flights during analyzed period at various airports

By tracking the chain of events, the benefit to airlines in terms of reduced delay for each SCS event could be estimated. The total benefit includes that to the airline initiating the SCS event (SUB benefit) and to other airlines that can bridge to the vacated slot (BRG benefit). Daily benefits from SCS, and the breakdown into SUB and BRG benefits, are shown in Figure 22.

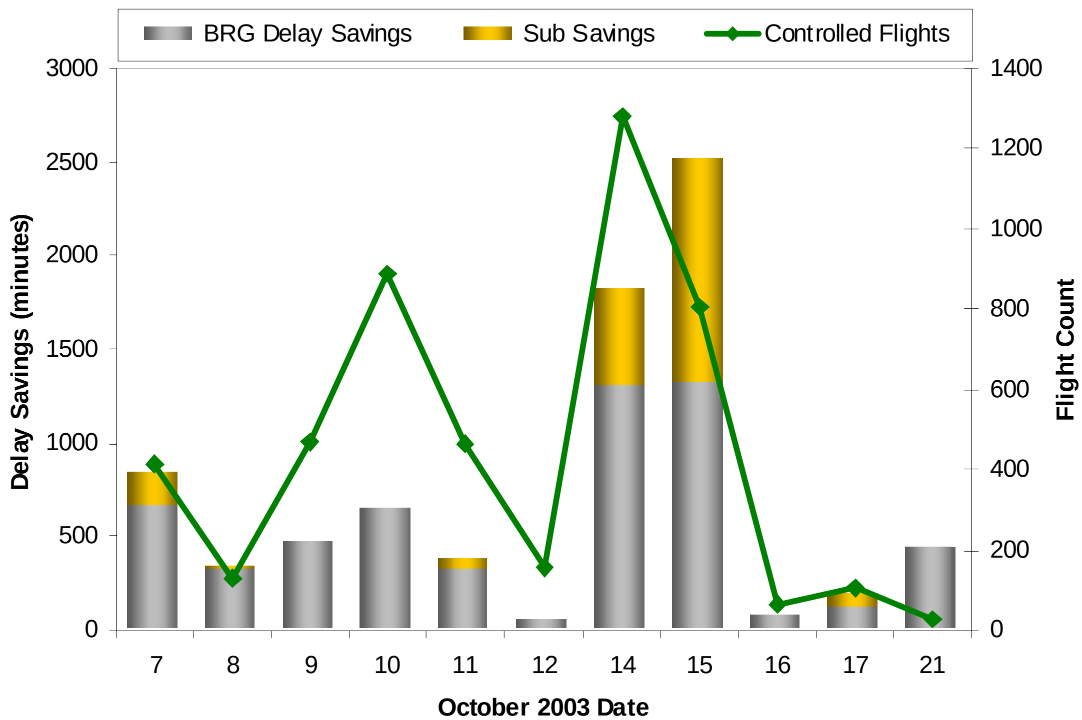

Figure 22. Delay savings for SCS events, broken into BRG and SUB categories

During the sampled period, BRG benefits totaled 5,672 minutes of delay savings and SUB benefits totaled 2,049 minutes of delay savings, for a total of 7,721 minutes of delay savings. Annually, there are approximately 172,000 controlled flights in GDPs, compared to the 4,800 during the sampled period. Scaling by the ratio of controlled flights allows an estimate of total annual SCS benefits of over 276,000 minutes of delay savings.

During the November CDM meeting, representatives of Northwest Airlines (NWA) also presented an estimate of benefits from SCS functionality [13]. NWA has seen an increase in the number of SCS subs submitted since May 2003. The airline has most frequently used SCS at Newark Liberty (EWR), Philadelphia (PHL), and LaGuardia (LGA) airports, where they have a limited schedule and flights often are not scheduled close enough together to use traditional subbing.

A sample scenario is a GDP at EWR on September 9, 2003, caused by runway construction. NWA flights were spaced over an hour apart, and most had significant expected delays (51-89 minutes) from the GDP. Due to the spacing between flights, any slots from cancelled flights could not be utilized by NWA with traditional subbing. However, by using SCS to obtain credit for slots from two cancelled flights, NWA was able to reduce delay on four other flights. Without the SCS capability, either none of the flights would have been canceled, or any cancelled flight's slots would have gone unused by NWA.

For the sampled month of May 2003, NWA estimates that using SCS credits from their own cancelled flights enabled 475 minutes of delay reduction at EWR alone, with a total value of $12,747.

Beyond the benefit of credits for their own cancelled flights, SCS participants also benefit when other airlines utilize SCS. The slot vacated by the cancelled flight can be claimed by another airline by bridging, resulting in a reduction of delay. Northwest has seen a significant increase in the number of bridged flights since September 2003, with most bridged flights moved up by around 30 minutes.

In total, NWA estimates that they saved over 6000 minutes of delay in September 2003 alone due to SCS subbing capability. NWA reports that they have been more likely to include cancelled flights in operational plans of recovery from a GDP, because they know they can bring other flights on time using SCS.

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ACRONYMS

AAR	Airport Acceptance Rates
ACDF	Adjacent Center Data Feed
AOS	Operational Support Office
AOZ	Free Flight Program Office
APR	Air Traffic Control Preferred Route
ARTCC	Air Route Traffic Control Center
ASD	Office of System Architecture and Investment Analysis
ASPM	Aviation System Performance Metrics
ASY	Office of System Safety
ATA	Office of Air Traffic Airspace Management
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATL	William B. Hartsfield Atlanta International Airport
BRG	Slot Credit Substitution Bridging Message
CAASD	Center for Advanced Aviation System Development
CCLD	Core Capability Limited Deployment
CCSD	Common Constraint Situation Display
CDM	Collaborative Decision Making
CHI	Computer Human Interface
CNAC	The CNA Corporation
CPDLC	Controller-Pilot Data Link Communications
CRCT	Collaborative Routing Coordination Tool
DEN	Denver International Airport
DFW	Dallas/Ft. Worth International Airport
ECR	EDCT Change Request
EDCT	Estimated Departure Clearance Times
ETMS	Enhanced Traffic Management System
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FCA	Flow Constrained Area
FEA	Flow Evaluation Area
FFP	Free Flight Program
GDP	Ground Delay Program
GPD	Graphic Plan Display
IAH	George Bush Intercontinental Airport
IDU	Initial Daily Use
IFR	Instrument Flight Rules
JTA	Jerry Thompson and Associates
LAX	Los Angeles International Airport
LGA	LaGuardia Airport
MIA	Miami International Airport
MIT	Miles-In-Trail

MSP	Minneapolis/St. Paul Airport
NAS	National Air Space
NASA	National Aeronautics and Space Administration
NEXTOR	National Center of Excellence for Aviation Operations Research
NWA	Northwest Airlines
PDARS	Performance Data Analysis and Reporting System
PHL	Philadelphia International Airport
PTR	Program Trouble Reports
SCS	Slot Credit Substitution
SCT	Southern California TRACON
SFO	San Francisco International Airport
SSWG	System Safety Work Group
SUB	Slot Credit Substitution Message
TBM	Time-Based Metering
TMA	Traffic Management Advisor
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control Facility
UPT	User-Preferred Trajectory
URET	User Request Evaluation Tool
ZAU	Chicago ARTCC
ZBW	Boston ARTCC
ZDC	Washington ARTCC
ZDV	Denver ARTCC
ZFW	Ft. Worth ARTCC
ZHU	Houston ARTCC
ZID	Indianapolis ARTCC
ZJX	Jacksonville ARTCC
ZKC	Kansas City ARTCC
ZLA	Los Angeles ARTCC
ZMA	Miami ARTCC
ZME	Memphis ARTCC
ZMP	Minneapolis ARTCC
ZNY	New York ARTCC
ZOA	Oakland ARTCC
ZOB	Cleveland ARTCC
ZTL	Atlanta ARTCC